Earth Retaining Structures Using Tiebacks

General Information

The Substructure Committee or Earth Retaining Systems Unit should be consulted for unusual conditions, and will assist with any structure design utilizing tiebacks if requested.

Basic procedures and criteria for design of earth retaining walls using tiebacks are as follows:

Subsurface Investigation

The designer must familiarize the Engineering Geologist with the nature of the structure before preliminary borings are made. The soils investigation is to provide the following data:

1. A log of borings sufficient in number, depth and lateral extent to encompass the anchor/tieback zone as well as the visible portions of the wall making it possible to characterize all the material therein.

2. Ground water levels.

3. Moisture content and soil densities at selected levels.

4. An evaluation of the shear strength of the material in the anchor zone and in the material to be retained by the wall. This data will include an evaluation of the basic soil strength parameters (density – γ, angle of shearing resistance – ϕ, and cohesion – C).

5. A discussion of conditions likely to be encountered in the drilling and placing of the tieback system. The discussion will focus on the anticipated ease or difficulty of drilling and what type of drilling equipment might necessarily be employed.

6. An estimate of allowable bearing capacity below the earth being retained.

Lateral Pressure Distribution

The active pressure condition which is employed in the design of cantilever walls may be unconservative in determining lateral pressures on a tiedback wall.

In the absence of specific recommendation from the Engineering Geology Branch of the Division of New Technology, Materials and Research, the pressure distributions shown in Figure 2 may be used for tiedback walls.

Additional pressure due to traffic or other surcharge should be evaluated and added to the basic pressure diagram.

Wall Design

The wall may consist of sheet piles with horizontal wales, vertical soldier piles with timber or concrete lagging between piles, or reinforced concrete such as the "slurry walls" employed in retaining deep excavations, or cast-in-place or "shotcrete" concrete walls built from the top down in cut sections.

Soldier piles may be full length reinforced concrete CIDH piles, steel "H" piles or heavy timber piles driven in place or placed in drilled holes which are backfilled with concrete.

Tiebacks are often placed directly through the soldier piles or may be placed between piles with the load transferred to adjacent piles by horizontal wales.

The soldier piles or sheet piles should be designed as beams subjected to the loading of the appropriate lateral pressure diagram.

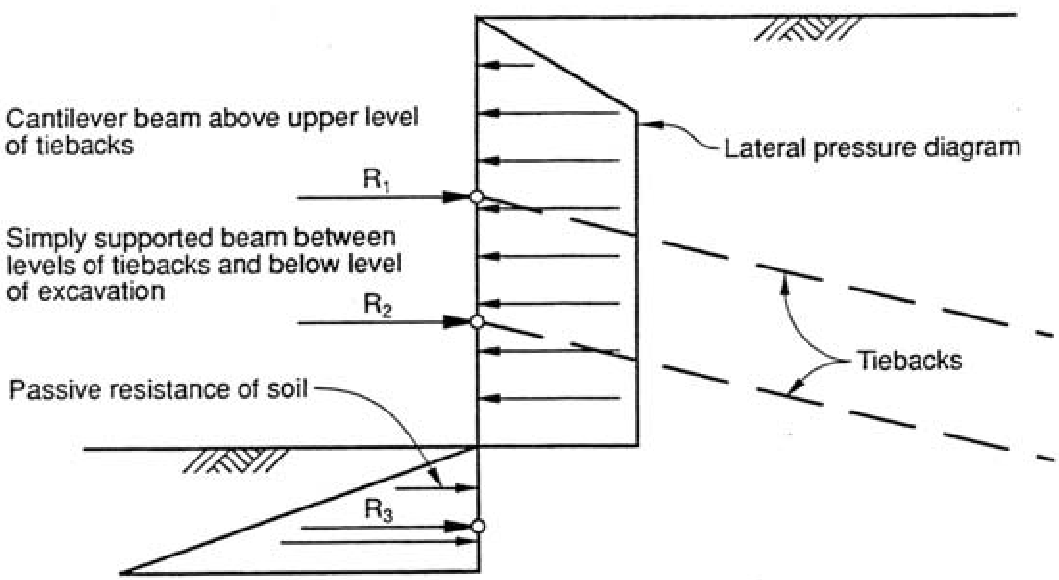


Figure 1

Horizontal wales should be designed as simple beams loaded by the reactions calculated from the lateral pressure diagram.

Spacing of soldier piles is governed by their capacity to resist lateral earth loads. Spacings of 6' to 10' have been used effectively.

The soil below the level of excavation must have sufficient bearing capacity to support the vertical component of the tieback force in addition to the dead load of the wall and the vertical component of earth pressure on the wall.

The wall embedment must be sufficient to resist the horizontal reaction at the bottom of the excavation.

Tiebacks

A tieback consists of a prestressing system (bars or strands) anchored in a drilled hole filled with PCC grout. Drilled hole diameters of 5 to 16 inches are commonly used.

Tiebacks are designed to provide the reactions determined in the calculation of soldier pile stresses. Prestressing steel design is based on a maximum stress of 0.55 f_{pu} at design load, or 0.75 f_{pu} at jacking load, (test load). (f_{pu} = specified minimum ultimate tensile strength.)

The distance between adjacent tiebacks should be large enough to avoid group action of the anchors. A distance of five feet at the beginning of the bond length of the anchor will be sufficient for most systems. Staggering of the anchor ends of the tiebacks is good practice to prevent surface cracks from developing above anchor ends.

Anchor capacity is based upon developing the friction and adhesion of the soil along the soil-anchor interface, or for belled-end anchors the shear strength of the soil at the surface of a cylindrical plug having a diameter equal to that of the bell (commonly 18 to 30 inches). The resistance along the soil-anchor interface is a function of the contractor's method of installation. The design of the anchor type and any anchor length in excess of the specified minimum length should be left up to the contractor. This provides an opportunity for competitive bidding by contractors with various types of anchoring systems.

Proof testing or performance testing of all permanent tiebacks to verify design capacity is mandatory and the test procedure is clearly spelled out in the Reference Spec. .i.500 TIEBACK. References 1 & 2 contain some background information on testing anchors. Specifications should clearly indicate that the contractor is responsible for the design to meet the test load requirements.

The design force "T" for each tieback should be indicated on the plans. The design force for tiebacks associated with earth retaining structures is the tieback force required to resist the design lateral earth pressure. The design force for tiebacks associated with slope stabilization is the tieback force required to provide a factor of safety against slope failure equal to 1.25 minimum. The test load for each tieback should be either 1.5 or 1.3 times the design force "T". The factor 1.5 should be used for tiebacks associated with permanent earth retaining structures. The factor 1.3 should be used for tiebacks associated with temporary earth retaining structures and structures that buttress unstable slopes (slope stabilization).

The unbonded or stressing length of the tieback should be extended beyond any possible soil failure planes and generally should be no shorter than 15 feet.

The minimum unbonded and bonded lengths for tiebacks and tiedowns should be shown on the plans in lengths to the nearest 5 feet.

Subsequent to successful testing of a tieback it should be stressed to a specified force and locked off against the structure. For most earth retaining structures the recommended lock off force equals 0.75 times "T". An exception to this is for the situation where it is desired to minimize structure movement, which case the recommended lock off force equals 1.00 times "T". An example of this situation is where a building is located adjacent to the top of an earth retaining structure.

Settlement

Application of the proper lateral pressure diagram in design and careful construction techniques should result in little or no settlement of adjacent ground.

Order of Work

Special Provisions

Construction sequence in sufficient detail to insure proper installation of tiebacks is to be covered in the special provisions. For walls in cuts the maximum allowable level of excavation below each tieback level should be specified since over-excavation will result in overstressing of preceding tiebacks or in undue settlement. Similarly, in walls that are to be backfilled, a sequence of placing tiebacks, back-filling and stressing should be specified in detail to prevent overstressing any members during construction.

Plans

The soil design parameters γ, ϕ, or C should be shown under the General Notes with a note indicating that these values are for wall design only. The log of test borings should include all test data including triaxial and pocket penetrometer tests.

Information shown on the plans for a tieback wall usually include but are not limited to the following:

- Design force of tiebacks
- Position and angle of inclination of tiebacks
- Minimum unbonded length of tieback tendon
- Minimum bonded length of tieback tendon
- Concrete compressive strength required at time of stressing

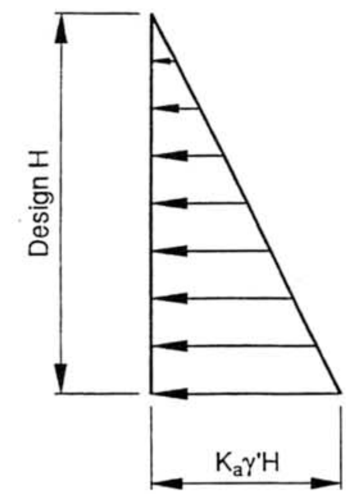
When test boring logs and subsurface information are used or is known to exist, but will not be included in the structure plans, a note to the Specifications Engineer should be included with the plans submitted to Specifications stating the existence of the additional subsurface information.

Special Considerations

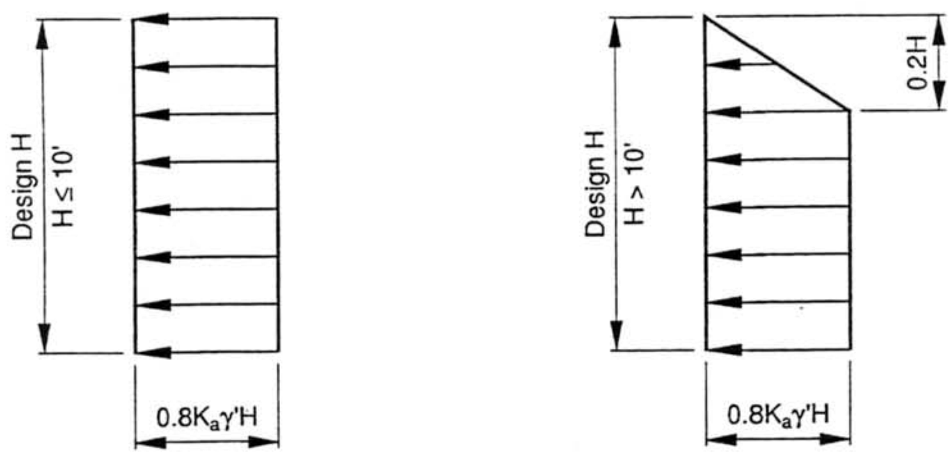
1. In addition to the dangerous conditions that can result from over-excavating before installation of tiebacks, the force in the tiebacks, especially when multiple levels are used in deep excavations, can create a circular slip plane resulting in settlement failure of the entire wall/tieback system.For this reason it is recommended that the lower tiebacks be lengthened to avoid a circular pattern of the ends of the tiebacks when more than two levels of tiebacks are used.

2. Heaving of the bottom of the excavation can occur in soft clays, resulting in settlements of the supported ground.

3. Neglecting to place lagging simultaneously with excavation progress, has caused major failures.



For Cantilever Walls or Walls with One Level of Tiebacks



Walls with Multiple Levels of Tiebacks

Notes:

K_a obtained by trial wedge analysis using Coulombs theory with wall friction angle (δ) assumed equal to zero.

γ' = effective unit weight of retained material.

Lateral pressures due to live load, adjacent structures or ground water should be added to the earth pressures indicated above.

Figure 2. Recommended Pressure Distributions for Tiedback Walls

References

1. Goldberg, D. T., Jaworski, W. E., and Gordon, M.D., "Lateral Support Systems and Underpinning," Report No. FHWA-RD-75-128, 129 & 130 (Vol. I – III), 1976.

2. "Recommendations for Prestressed Rock and Soil Anchors," Post-Tensioning Institute, 1985.

3. "California Trenching and Shoring Manual," Caltrans, Division of Structures, 1990.

4. "Steel Sheet Piling Design Manual," U. S. Steel, 1975.

5. "Design Manual Soil Mechanics, Foundations, and Earth Structures," Dept. of the Navy, Naval Facilities Engr. Command (NAVFAC DM-7), 1982.

6. Tschebotarioff, Gregory P., "Foundations, Retaining and Earth Structures," McGraw Hill, 1973.

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